LC/NAIROBI

ECA/POP/WP/87/4(1.4(ii))

POPULATION PROJECTIONS AND ESTIMATES

SUBNATIONAL LEVEL

Paper prepared by Dr Ita I. Ekanem, Chief, Planning and Policies Section, ECA, Population Division for presentation at a Seminar-cum-Workshop on 'Development Planning and Demographic analysis: the case of Ethiopia' scheduled for October to , 1987. The views expressed in the paper are those of the author and not those of the United Nations.

I. INTRODUCTION

1. This lecture will focuss on subnational projections. The uses of population projections in development planning are briefly outlined. The methodology of obtaining population projections for the subareas of a nation based on the national projections is then described in some detail. An illustration of one of the techniques for subnational projections using data from Ethiopia is then presented.

(i) Uses of population projections

2. National projections constitute an indispensable part of the statistical basis for planning socio-economic development and other governmental programmes. In the developed countries, the necessity of planning for the achievement of public goals is recognized and population projections are used in planning activities and investments in the private as well as the public sectors (Baum, 1981). Among the developing countries the extent to which population projections are applied in planning varies with the avalability of demographic data and other resources for preparing projections.

3. In addition, population projections serve to illuminate questions of policies for coping with the consequences of population trends as well as policies for influencing them (Isupou, 1981). In countries where population policies are established, demographic targets and programmes of action designed to achieve these targets are commonly incorporated in development plans. Population projections are useful in defining such targets; formulating such plans for action; and thus serve to evaluate the realism of proposed demographic targets as well as the adequacy of proposed measures for attaining them.

4. Sometimes, population projections are also designed as analytical instruments to study the influences of mortality, fertility and migration on population growth and structure; to assess the effects of demographic factors on economic and social development; and, to estimate the impact of policy measures on fertility and population growth. Demographers also use projections as aids in evaluating and correcting demographic data as well as for experimenting with methods of projection (Inoue, 1981).

5. In addition to national planning, subnational planning provides an opportunity to mobilize the human resources of an area through community development, for economic and social progress at the local level but within the framework of national development goals. The location of industries and the development processes such as housing, commerce and the provision of public services and facilities should be based on regional aspects. The importance of population distribution and subnational projections in regional and sectoral planning is, therefore, universally acknowledged. Conceivably, subnational projections are more important for a large country with diverse cultural segments in the population than for a small, homogeneous country.

(ii) Considerations of data and methodology

6. The various methods for preparing national and subnational projections are well documented.1/ The methods of making subnational projections are in many respects similar to those used in projecting national populations. As for national projections, the data required fall into two broad classes: (a) benchmark population data, vital statistics (birth, deaths and migration) and other regularly collected administrative data which can provide measures of components of population changes; and (b) estimates of future trends in the growth components. If those data are available per subarea, the cohort-component method can be used to project the population of each subarea, and aggregated to obtain the national projection. Several practical problems, however, militate against that procedure.

7. First, boundaries of States, districts, etc., very often change and adjustments are very difficult when estimating inter-censal population growth and its components. Not only do adjustments have to be made for such changes in estimating past population growth and its components, the projection methodology has to take into account future shifts in the status of localities from rural to urban and vice versa. Boundary changes also create problems in estimating net inter-censal migration, especially from the data obtained by some of the usual census questions on migration. Moreover, subnational projections are often constrained by the availability of independently made national projections. The sum of the populations of all subarea units should add up to the national totals in each age-sex group.

8. Secondly, the primary difference between national and subnational projections is the relative importance of the migration component. In almost all the member States, population growth rates vary significantly from one part to another largely owing to internal migration. For making subnational projections, data on in- and out-migration are more desirable than data on net migration alone. The former are less abundant than the latter, at least with the detail that is needed for population projections. Thus, lack of suitable data on migration is one of the basic problems of making subnational population projections. Furthermore in the absence of satisfactory vital registration data, the levels of fertility or mortality for urban and rural sectors, cities, regions, etc., often cannot be estimated reliably from data on the sex-age composition of the population, because of the distorting effect of migration.

9. The migration data needed for subnational projections are the amount of net migration classified by age and sex for each area unit and for each time interval for which the projections are to be made. The principal source of such data is the population census. Sample surveys and population registers also provide some information. Measures of gross migration flows require a direct question in the census. The usual direct questions are place of birth, place of previous residence, place of usual residence, duration of residence and place of

---

1/ The available methods include: (i) calculating the speed of doubling and rate of growth, (ii) polymonials and other functions of time; (iii) the component approach; etc. For details of these and other methods, see El-Badry, M.A. "Demographic projections in historical perspective", in Population Projections: Problems and solutions (United Nations: New York, 1981), pp.62-71.

residence at a fixed prior date (United Nations 1970); Shryock, 1964; Bach, 1965, Adepoju et.al, 1976). The inherent problems of information derived from each of those questions are well documented (UNECA, 1986).

10. In the absence of information from the direct migration questions, estimates of net migration by age and sex for subareas can be made from age distributions at two censuses. The method requires estimation of inter-censal survival ratios from the census data or from life tables. The use of the census survival ratios, however, has problems. The error will be greatest when mortality rates are high; when the amounts of in-migration and out-migration differ considerably; and/or when most of the migration took place near the beginning of the inter-censal period. Such errors can be partly eliminated if survival ratios are calculated separately for each subarea. This is possible if birth place data are available by age and sex for two censuses. Then survival ratios can be calculated separately for those born in various subareas. When census survival methods cannot be applied (owing to lack of data), life table survival ratios can be used to estimate net migration (UNECA, 1986).

11. Age misreporting and the lack of data on national life tables made the estimation of migration for subareas difficult, if not impossible, for most member States. The projection of migration for future time period is inherently more difficult than the projection of fertility and mortality. Changes in fertility and mortality are gradual and short-term fluctuations are relatively minor. The behaviour of migration rates is not comparable; they are more volatile and are determined by changing economic and political factors (Zachariah, 1981). However, some information on the determinants of migration is now available. Although knowledge is not perfect, it is known that (i) economic factors play a major role in internal migration; (ii) areas with rising employment opportunities attract more migrants than those with a stagnant economy; (iii) migrants tend to move from areas of low wages to areas of high wages; and (iv) rural out-migration is influenced by the level and nature of rural education.

12. Admittedly, such interrelationships are not universal, but they are sufficiently general and several attempts have been made to convert them into econometric equations. The use of such equations to predict future migration trends is however circumscribed by a number of factors. Regression coefficients estimated from the data of a particular country at a particular period of time are not sufficiently universal to be used for other countries and other periods of time. It is as difficult to predict future values of the "criterion variable" in the regression equation (e.g. wage differences)as it is to project migration rates without their use. Migration functions, as presently available, are not of much help in predicting future trends. Thus past migration trends remain one of the best predictors of future migration. More information on past trends is not available, ad hoc assumptions are indispensable (Zachariah, 1981).

13. In general the methods for preparing subnational projections can be grouped into three categories: demographic techniques, mathematical models and miscellaneous methods. Demographic techniques such as the cohort component method used in projecting national populations can also be used for subnational projections.

However, problems of boundary changes and internal migration, as well as the difficulty of obtaining accurate estimates of fertility and mortality for subareas in the face of the compounding effects of migration, militate against such use of the cohort component method. Miscellaneous techniques include projections through economic and/or social analysis, the holding-capacity method and analogy method. Among the mathematical methods, the ratio method has been shown to be superior to the others and more readily applicable to the data usually available in the ECA member States.

14. Given the foregoing, the next section of the lecture outlines an alternative to the cohort-component method (the ratio method) for deriving subnational projections. The method assumes that the physical land areas of the subnational groups remain the same over time. The assumption may be true with subnational population projections for regions, provinces and districts. In the case of rural-urban projections, it may not be realized, because urban areas do grow by addition of new areas fromerstwhile rural communities which attain urban status over time . As discussed below, the technique requires data for the subnational areas for at least two points in time. But as is well known, Ethiopia only took its first census in 1984. Several sample surveys have however, been taken before then in a bid to provide some estimateof the country's population together with the associated growth components. To illustrate the method, data from two of those surveys (the 1968-71 and 1980-81 rural demographic surveys) will be used.

II. THE RATIO METHOD

(i) Data requirements, assumptions and methodology

15. The ratio method requires data on (i) an independently derived projection of the total population of the country by age and sex; and (ii) a distribution of the national population for each of the subnational areas as observed for at least two points in time as well by age and sex for at least one point in time. It is assumed that the average annual rate of change in the population proportions, as observed in each sub-area between the two points in time, will decline linearly to zero within the next 30 years. That is to say, if for a given sub-area the annual growth rate was r, it will be r(1-1/30) after one year, r(1-2/30) after two years,..... and r(1-t/30) after t years (Shryock and Siegel, 1971). Basically, the application of the method is based on the premise that age-sex data are available for each sub-area of a country and for the whole country, at least for the latest census year. The ratio method provides a means of distributing the projected national population at future dates by age and sex for each sub-area per projection period.

16. In order to apply the method, the first step is to calculate the proportional distribution of the national population by sub-area for each date for which data are available. The second step is to derive annual exponential growth rates (r) for those proportions. If data on the distribution of the sub-areas are available

for only two time periods (t_1 and t_2), the annual growth rates so computed can either increase (i.e., r_{12} is positive), decrease (i.e., r_{12} is negative) or remain constant (i.e., the proportions at times t_1 and t_2 are the same and $r_{12} = 0$). If data are available for three points in time the proportions could either (a) remain constant, (b) increase or decrease continuosly or (c) increase/decrease during the first period and decrease/increase during the next period.

17. Consider the two-census case in a nation with, say, four sub-areas. The proportions of the national population in the subareas at the first census can be represented by R_{11}, R_{21}, R_{31} and R_{41}; the corresponding proportions at the second census can similarly be represented by R_{12}, R_{22}, R_{32} and R_{42}. These can be represented schematically as:

Sub-area	Proportions of total Population	
	First census	Second census
1	R_{11}	R_{12}
2	R_{21}	R_{22}
3	R_{31}	R_{32}
4	R_{41}	R_{42}
Country	1.000	1.000

.....(1)

Similarly, for a three-census situation in a country with four subareas, the proportions can be represented as:

Sub-areas	Proportions of total populations		
	First Census	Second census	Third census
1	R_{11}	R_{12}	R_{13}
2	R_{21}	R_{22}	R_{23}
3	R_{31}	R_{32}	R_{33}
4	R_{41}	R_{42}	R_{43}
Country	1.000	1.000	1.000

.....(2)

It is easy to develop the scheme for situations with more than three censuses and more than four subareas. In all cases, to project the proportions from their values at the latest census into the future, the practice is to take the latest census year as the base year.

18. The third step in the ratio method is to obtain the annual growth rates for these proportions at the selected base date. In the two - census case, the growth of the population proportions per subarea in the base year itself is assumed as half that so derived. Let the annual growth rate for R_{11} and R_{12} in the scheme (1) above be r_{12} and negative (i.e $R_{11} \leq R_{12}$). The assumed growth rate in the base year would be:

$$r_b = -1/2(r_{12}) \quad \ldots\ldots\ldots\

For periods other than 5 years, it is better to actually derive the value for r_{b+t} where t differs from 5 years. Thus if t = 4, for example then

$$r_{b+4} = r_b(1-1/30)(1-2/30)(1-3/30)(1-4/30) \quad \ldots\ldots\ldots\ldots\ldots\ldots \quad (7)$$

20. In the case of the three-census situation, the base year annual growth rate is obtained as follows: (a) when the proportions are constant, the growth rate is zero; (b) when it increases or decreases continuously, the base growth rate is the smaller in absolute value of annual growth rate between the first and last census and that between the second and last census, the sign (+ or -) being taken from the observed direction; and (c) when the trend in the proportions has been different in the two inter-censal periods, the base growth rate is taken as half of the growth rate between the second and last census. As in the two-census case, for a five-year period of projection the assumed r can be derived using the relationship in equation (6) above.

21. In all cases, the ratios are projected by geometric progression and it is also required that the sum of the projected ratios should be adjusted by prorating to keep the sum of the proportions for all subareas at unity. The proportions so adjusted then constitute the base year proportions for the next five-year projection period. The projected proportions for each subarea multiplied by the projected population of the country as a whole yields the projected population of the subarea.

22. Again consider the two-census case using the schema in (1) above. Let the population proportion in the subarea 1 five years from the second census be denoted by ${}_5R'_{12}$. Using the projected annual growth rate in equation (6) above,

$${}_5R'_{12} = R_{12}[1+r_b(1-1/30)][1+r_b(1-2/30)][1+r_b(1-3/30)][1+r_b(1-4/30)]$$
$$[1+r_b(1-5/30)] = R_{12}[1+r_b(1-3/30)]^5 \quad \ldots\ldots\ldots\ldots\ldots\ldots \quad (8)$$

For projecting the proportions for the other subareas, the relationship in equation (8) is used with appropriate values of base proportions and growth rates. As for the relation in (6) above, where the period differs from 5 years, the actual values should be derived. For 4 years,

$${}_4R'_{12} = R_{12}[1+r_b(1-1/30)][1+r_b(1-2/30)][1+r_b(1-3/30)][1+r_b(1-4/30)] \ldots\ldots \quad (9)$$

23. The fifth step is to obtain the age-sex distribution of the projected population per subarea. For the sex distribution, the trend in the sex ratio per subarea is used as the basis for determining the future trend. Consider the two-census situation. If the reported sex ratios at the two censuses for, say, subarea 1 show an increasing trend, the computed annual change therein is multiplied by 5 and added to the sex ratio at the second census to obtain the projected sex ratio for subarea 1, five years after the second census. The same procedure is adopted where the sex ratios at the two censuses show a decreasing trend, except that in this case the computed annual change multiplied by 5 is subtracted from the sex ratio at the second census. In the three-census case, if the trend in the observed sex ratios indicates a continuous decrease (or increase), the annual rate of change is based on the sex-ratio values at the first and third censuses. However, if the trend is in opposite directions over the two inter-censal intervals, the annual change is taken as one-half of the difference between the sex ratios for the second and third census years, divided by the time gap with the associated sign maintained. The rest of the procedure for projecting the sex ratio for five years after the third census remains unchanged.

24. Having derived the projected sex ratio for a date five years after the latest census, the sex distribution of the corresponding projected total population per subarea is easily deduced. This distribution is then summed over all the subareas to obtain an estimate of the projected population of the country as a whole, for males and females separately. For each sex, the corresponding independently projected total population for the country (based on the national projections) is utilized to adjust pro rata the sex distribution of the population in each subarea.

25. As a sixth step, the age distribution of the population by sex and subarea can then be obtained by means of the two-way raking procedure. To illustrate the use of this procedure (for either of the sexes), consider the scheme in table 1, which contains 17 quinquennial age groups (0-4, 5-9, 10-14, ... 75-79, 80+) and a simplified example of a country with four subareas. The scheme in table 1 is thus a 17 x 4 matrix. The total population by sex per subarea, as already derived, corresponds to $M_{18,1}$, $M_{18,3}$, and $M_{18,4}$ for the four subareas. The procedure adopted requires the values of the matrix elements in table 1 as well as $5M_{1,5}$.....$5M_{17,5}$ and $5M_{18,5}$ (i.e., the national population by age group and sex projected five years into the future and the corresponding total population by sex in the subareas).

26. The national population projection gives the first set of values and the ratio method just described provides the population by sex and by subareas. The need is to obtain the missing elements $5m_{1,1}$, $5m_{1,2}$, $5m_{1,3}$, $5m_{1,4}$, $5m_{2,1}$, ... $5m_{17,1}$, $5m_{17,2}$, $5m_{17,3}$ and $5m_{17,4}$ (table 2), in order to obtain the age composition five years later of the population of the subareas by sex. The method consists in pro-rating first the horizontal totals and then the vertical totals successively till both the horizontal and vertical totals tally with the values in the table margin which are already known. For instance, to obtain the population aged 0-4 for subarea 1 five years after base date, use is made of the following equation:

$$5m'_{1,1} = m_{1,1}\,(5M_{1,5}/M_{1,5}) \quad \ldots\ldots (10)$$

Similarly, for the age group 5-9:

$$5m'_{2,1} = m_{2,1}\,(5M_{2,5}/M_{2,5}) \quad \ldots\ldots (11)$$

Similar equations apply for other age groups up to 75-79:

$$5m'_{16,1} = m_{16,1}\,(5M_{16,5}/M_{16,5}) \quad \ldots\ldots (12)$$

In the case of subarea 2, the corresponding equations are:

$$5m'_{1,2} = m_{1,2}\,(5M_{2,5}/M_{2,5}) \quad \ldots\ldots (13)$$

$$5m'_{2,2} = m_{2,2}\,(5M_{2,5}/M_{2,5}) \quad \ldots\ldots (14)$$

Table 1 Schema for a two way raking procedure for deriving the age distribution for a given sex in a country with four subareas: The base-year populations

Age groups	Population in subarea				National Population
	1	2	3	4	
0-4	$m_{1,1}$	$m_{1,2}$	$m_{1,3}$	$m_{1,4}$	$M_{1,5}$
5-9	$m_{2,1}$	$m_{2,2}$	$m_{2,3}$	$m_{2,4}$	$M_{2,5}$
10-14	$m_{3,1}$	$m_{3,2}$	$m_{3,3}$	$m_{3,4}$	$M_{3,5}$
15-19	$m_{4,1}$	$m_{4,2}$	$m_{4,3}$	$m_{4,4}$	$M_{4,5}$
20-24	$m_{5,1}$	$m_{5,2}$	$m_{5,3}$	$m_{5,4}$	$M_{5,5}$
25-29	$m_{6,1}$	$m_{6,2}$	$m_{6,3}$	$m_{6,4}$	$M_{6,5}$
30-34	$m_{7,1}$	$m_{7,2}$	$m_{7,3}$	$m_{7,4}$	$M_{7,5}$
35-39	$m_{8,1}$	$m_{8,2}$	$m_{8,3}$	$m_{8,4}$	$M_{8,5}$
40-44	$m_{9,1}$	$m_{9,2}$	$m_{9,3}$	$m_{9,4}$	$M_{9,5}$
45-49	$m_{10,1}$	$m_{10,2}$	$m_{10,3}$	$m_{10,4}$	$M_{10,5}$
50-54	$m_{11,1}$	$m_{11,2}$	$m_{11,3}$	$m_{11,4}$	$M_{11,5}$
55-59	$m_{12,1}$	$m_{12,2}$	$m_{12,3}$	$m_{12,4}$	$M_{12,5}$
60-64	$m_{13,1}$	$m_{13,2}$	$m_{13,3}$	$m_{13,4}$	$M_{13,5}$
65-69	$m_{14,1}$	$m_{14,2}$	$m_{14,3}$	$m_{14,4}$	$M_{14,5}$
70-74	$m_{15,1}$	$m_{15,2}$	$m_{15,3}$	$m_{15,4}$	$M_{15,5}$
75-79	m_{16}	$m_{16,2}$	$m_{16,3}$	$m_{16,4}$	$M_{16,5}$
80+	$m_{17,1}$	$m_{17,2}$	$m_{17,3}$	$m_{17,4}$	$M_{17,5}$
All ages	$M_{18,1}$	$M_{18,2}$	$M_{18,3}$	$M_{18,4}$	$M_{18,5}$

Table 2 Schema for deriving the age distribution of the projected total population (by sex) and subarea

Age groups	Base date (latest census)					First projection (five years later)				
	Sub-areas					Sub-areas				
	1	2	3	4	Total	1	2	3	4	Total
0-4	$m_{1,1}$	$m_{1,2}$	$m_{1,3}$	$m_{1,4}$	$M_{1,5}$	$5m_{1,1}$	$5m_{1,2}$	$5m_{1,3}$	$5m_{1,4}$	$5M_{1,5}$
5-9	$m_{2,1}$	$m_{2,2}$	$m_{2,3}$	$m_{2,4}$	$M_{2,5}$	$5m_{2,1}$	$5m_{2,2}$	$5m_{2,3}$	$5m_{2,4}$	$5M_{2,5}$
10-14	$m_{3,1}$	$m_{3,2}$	$m_{3,3}$	$m_{3,4}$	$M_{3,5}$	$5m_{3,1}$	$5m_{3,2}$	$5m_{3,3}$	$5m_{3,4}$	$5M_{3,5}$
15-19	$m_{4,1}$	$m_{4,2}$	$m_{4,3}$	$m_{4,4}$	$M_{4,5}$	$5m_{4,1}$	$5m_{4,2}$	$5m_{4,3}$	$5m_{4,4}$	$5M_{4,5}$
20-24										
25-29										
30-34	$m_{7,1}$	$m_{7,2}$	$m_{7,3}$	$m_{7,4}$	$M_{7,5}$	$5m_{7,1}$	$5m_{7,2}$	$5m_{7,3}$	$5m_{7,4}$	$5M_{7,5}$
35-39	$m_{8,1}$	$m_{8,2}$	$m_{8,3}$	$m_{8,4}$	$M_{8,5}$	$5m_{8,1}$	$5m_{8,2}$	$5m_{8,3}$	$5m_{8,4}$	$5M_{8,5}$
40-44										
45-49										
50-54										
55-59										
60-64										
65-69										
70-74										
75-79										
80+	$m_{17,1}$	$m_{17,2}$	$m_{17,3}$	$m_{17,4}$	$M_{17,5}$	$5m_{17,1}$	$5m_{17,2}$	$5m_{17,3}$	$5m_{17,4}$	$5M_{17,5}$
TOTAL	$M_{18,1}$	$M_{18,2}$	$M_{18,3}$	$M_{18,4}$	$M_{18,5}$	$5M_{18,1}$	$5M_{18,2}$	$5M_{18,3}$	$5M_{18,4}$	$5M_{18,5}$

$$ {}_5m'_{16,2} = m_{16,2} \left({}_5M_{16,5} / M_{16,2} \right) \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (15) $$

Corresponding equations apply to subareas 3 and 4 (in this illustrative example).

27. Using the results of this last step, the projections for the 17 age groups are added together for each subarea and the totals compared with the corresponding projected total populations by sex and subarea, whose computation has been discussed above (i.e., with ${}_5M_{18,1}$; ${}_5M_{18,2}$; ${}_5M_{18,3}$; and ${}_5M_{18,4}$). For subarea 1, for example, let ${}_5m'_{1,1} + {}_5m'_{2,1} + {}_5m'_{3,1} + \ldots\ldots\ldots + {}_5m'_{17,1} = {}_5M'_{18,1}$, which is then compared with ${}_5M_{18,1}$ (table 2). The same is done for all the other sub areas: ${}_5M'_{18,2}$ obtained by addition and compared with ${}_5M_{18,2}$ for subarea 2; similarly ${}_5M'_{18,3}$ with ${}_5M_{18,3}$ for subarea 3; and ${}_5M'_{18,4}$ with ${}_5M_{18,4}$ for sub-area 4. If they are all equal (i.e., ${}_5M'_{18,i} = {}_5M_{18,i}$ for $i = 1,2,3,4$), the raking process is complete.

28. In practice, it may be quite difficult to ensure that this is exactly so. A practical step is to regard the raking process as completed if the differences between each pair of values lie, say, in the range 0 to 5. If this condition is not met, adjust the cell entries in the four columns of the matrix so that ${}_5M_{18,1} = {}_5M'_{18,1}$; ${}_5M_{18,2} = {}_5M'_{18,2}$; etc. and then check for horizontal agreement (i.e., whether ${}_5M'_{1,5} = {}_5M_{1,5}$, etc.). If that is not the case, adjust pro rata the rows and check for vertical agreement. Continue pro rata adjustment horizontally and vertically until all the summations (horizontal and vertical) agree with the projection values in the table margin.

29. Admittedly the foregoing two-way raking process, though simple and straightforward, is quite tedious. The entire process calls for care and painstaking effort. It should be much easier to use a computer programme than manual computation to accomplish it. The ECA secretariat has developed such a programme.

(iii) An illustration of the ratio method with Ethiopian data

30. From the 1968-71 and 1980-81 sample surveys of Ethiopia, data are available on the age-sex distribution of the rural population for 12 of the 14 regions (subareas) that comprise Ethiopia. The relevant data on the geographical distribution of the rural population and on sex ratios are shown in table 3.

31. As an illustration of the application of the ratio method, using the two-way raking process described above, to the rural survey data of Ethiopia the age-sex distribution of the population for each of the 12 regions will be projected four years from the last survey in 1981, taken as base year. Table 4 shows the calculation of the projected annual growth rates and sex ratios 1970-81 by region. Table 5 shows the projected population proportions by region, using the procedures described above, and hence the projected regional population for January 1, 1985. For instance, in the Arssi region, the annual growth rate in the proportion between 1970 and 1981 is:

$$r_{12} = \frac{1}{11} \ln \frac{.050002}{.042983} = .013751$$

Since the data are available for only two time periods (1970-81), the assumed growth rate for Arssi in 1981 is one half the 1970-81 rate, that is:

$$r_b = \frac{1}{2} \text{ of } .013751 = .006876$$

where b = 1981 (in this case).
The assumed base-year growth rates are shown in table 4 for all the 12 regions.

32. The projected annual growth rates for the period 1981-1985 are obtained from equation (7) above. For the Arssi region:

$$r_{b+5} = r_{1981-1985} = r_{1981}(1-1/30)(1-2/30)(1-3/30)(1-4/30)$$

$$= .006876 \times .966667 \times .933333 \times .9 \times .866667 = .004839$$

Similarly - .009396 and - .003650 are obtained for the Bale and Gondar regions, respectively. Based on these projected growth rates table 4), the projected population proportions are obtained from equation (9) above. For the Arssi region for example, the projected proportion of the rural population for 1985 is given by the product of the base-year (1981) proportion and the projected compounded annual rate of change over the projection period. That is:

$$R_{1985} = R_{1981}[1+r_{1981}(1-1/30)][1+r_{1981}(1-2/30)][1+r_{1981}(1-3/30)]$$
$$[1+r_{1981}(1-4/30)]$$

$$= .050002[1+.006876(.966667)][1+.006876(.933333)][1+.006876(.9)]$$
$$[1+.006876(.866667)] = .050977$$

Table 3: Distribution of estimated rural population and sex ratios by region: Ethiopian sample surveys, 1968-71 and 1980-1981

Region	Rural Population				Sex ratios	
	Numbers (000s)		Proportions		Jan. 1 1970	Jan. 1 1981
	Jan. 1, 1970	Jan. 1, 1981	Jan. 1, 1970	Jan. 1, 1981		
Arssi	802	1,411	.042983	.050002	101.4	101.6
Dale	659	743	.035319	.026330	99.0	98.3
Gondar	1,519	2,050	.081427	.072646	106.8	114.9
Gemu Gofa	749	944	.040143	.033453	101.6	102.8
Gojam	1,509	2,302	.080876	.081789	103.4	104.6
Hararge	2,276	3,252	.121982	115242	105.5	106.0
Illubabor	588	735	.031515	.026046	104.2	97.7
Keffa	1,194	2,065	.063993	.073178	101.5	101.3
Shoa	3,885	6,442	.208219	.228284	103.2	102.9
Sidamo	2,078	3,107	.111372	.110103	104.8	108.8
Wollega	1,529	1,964	.081948	.069599	98.6	98.9
Wollo	1,870	3,198	.100223	.113328	114.6	103.3
Rural Ethiopia[a/]	18,658	28,219	1.000000	1.000000		101.5

a/ Excludes the two regions of Eritrea and Tigrai

Source: The estimate for January 1, 1981 derives from Report on the results of the 1981 Demographic Survey, Statistical Bulletin No. 46 (Central Statistical Office: Addis Ababa, June 1985), Table 5, pp ix -12 for Jan. 1970, the estimates derive from Results of the National Sample Survey (Second Round), Vol. 1, Statistical Bulletin No. 10 (Central Statistical Office: Addis Ababa, January 1974), Table 1.3, pp. 6-13.

Table 4: Annual rate of change in the population proportions, assumed base year (1981) growth rate and projected annual growth rates/sex ratios,1985 for regions of rural Ethiopia

Region	Annual rate of change in the proportions (1970 - 1981)	Assumed base year (1981) rate of growth	Projections for 1985	
			Rate of growth of proportions	Sex ratios
Arssi	.013751	.006876	.004839	101.7
Bale	- .026701	- .013351	- .009396	98.0
Gondar	- .010374	- .005187	- .003650	117.1
Gemu Gofa	- .016573	- .008287	- .005832	103.2
Gojam	.001021	.000511	.000360	105.0
Hararge	- .005167	- .002584	- .001818	106.2
Illubabor	- .017327	- .008664	- .006097	95.3
Keffa	.012193	.006097	.004291	101.2
Shoa	.008364	.004182	.002943	102.3
Sidamo	- .001042	- .000521	- .000367	110.3
Wollega	- .014849	- .007425	- .005225	99.0
Wollo	.011172	.005586	.003931	99.2

Source: Derived from Table 3

Table 5: Projected population proportions and numbers for regions of rural Ethiopia, January 1, 1985

Region	Projected proportion	Adjusted proportion	Projected population (000s)
Arssi	.050977	.050927	1710
Bale	.025354	.025329	850
Gondar	.071591	.071521	2401
Gemu Gofa	.032679	.032647	1096
Gojam	.081907	.081827	2747
Hararge	.114406	.114295	3837
Illubabor	.025417	.025392	852
Keffa	.074442	.074370	2497
Shoa	.230983	.230758	7748
Sidamo	.109942	.109835	3687
Wollega	.068156	.068090	2286
Wollo	.115121	.115009	3861
Rural Ethiopia	1.000975	1.000000	33572

N/B. Total estimated rural population as at July 1, 1985 = 38525[a/] (i.e. 43557-5032)

But Eritrea and Tigrai regions constitute about 11.9% of the total rural population of Ethiopia.[b/] Hence the estimated rural population of Ethiopia excluding Eritrea and Tigrai regions equals 38525 less 11.9% of 38525 i.e. 33,940

By pro rating, this equals 33572 as at January 1, 1985.

a/ See World Population Prospects as assessed in 1984 (United Nations: New York, 1986), p. 196.

b/ The estimate of 11.9% derives from Statistical Bulletin No. 46, op.cit, Table 5

Source: Derived from Table 4

Table 5 shows the initially projected proportions for the 12 regions, together with the values adjusted to ensure a sum of unity. The projected rural population (both sexes) of Ethiopia in 1985 is then distributed over the regions with the aid of the adjusted proportions.

33. To obtain a distribution of these projected regional populations by sex, the trend in the observed regional sex ratios (table 3) is used to project sex ratios for 1985. Consider the Arssi region, for example. The observed sex ratio showed an increase from 1967 to 1981. The annual change in the sex ratio is accordingly taken as:

$$\left(\frac{101.6-101.4}{11}\right) = .018182$$

Hence the sex ratio for the Arssi region in 1985 is taken as

$$101.6 + (4 \times .018182) = 101.7$$

In table 4 the projected sex ratios for 1985 are shown; in table 6, the implied related populations by sex and the adjusted (pro-rated) populations by sex are shown. The adjustment is needed to ensure that the total population for all regions equals the projected rural population of Ethiopia by sex in 1985. The adjustment factors are for males and females 16911/17136 and 16661/16436, respectively.

34. The two-way raking technique described above is then applied to the regional male and female population projections for 1985 in order to obtain their age distributions. There are 17 five-year age groups (0-4, 5-9, ..., 80+) and hence the raking process should involve a 17 by 12 matrix (table 7).

35. By the two-way raking process, the projected male population aged 0-4 for the Arssi region in 1985 is derived as follows, starting with the basic data in table 7. The first iteration gives:

143(851/711) = 171) which is the cell entry in table 8.

For the age group 5-9, the corresponding iteration gives 137(851/711) = 164; and for the age group 80+, it is 7(851/711) = 8. Table 8 shows a total projected derived male population for all 12 regions of 3,009,000 for ages 0-4; 3,002,000 for ages 5-9; and 214,000 for ages 80+. The corresponding values for females were 170,000, 2,899,000 and 2,959,000, respectively. Since these derived totals differ from the national projections by age and sex for rural Ethiopia (last column per sex of table 8), each cell entry per age group, sex and region in table 8 is pro-rated, so as to bring the derived totals into line for each age group and sex with the corresponding national projection. Adding vertically, the derived column totals are obtained (last row per sex of table 9), and compared with the corresponding projected regional totals (last row per sex of table 8). This process is continued until the final age and sex distribution shown in table 10 is obtained. If the derived row and column totals of the final iteration were inserted in table 10, it would be seen that they are very close to the corresponding national projections shown as rows in table 8 and columns in table 9, respectively.

Table 6. Projected population by sex for regions of rural Ethiopia, Jan. 1, 1985

	Implied population by Sex		Adjusted population by sex	
	Male	Female	Male	Female
Aresi	862	848	851	860
Bale	421	429	415	435
Gondar	1,295	1,106	1,278	1,121
Gemu Gofa	582	514	574	521
Gojam	1,407	1,340	1,389	1,353
Harrarge	1,976	1,861	1,950	1,886
Illubabor	416	436	411	442
Keffa	1,256	1,241	1,240	1,258
Shoa	3,927	3,821	3,874	3,873
Sidamo	1,934	1,753	1,909	1,777
Wollega	1,137	1,149	1,122	1,165
Wollo	1,923	1,938	1,898	1,965
Rural Ethiopia	17,136	16,436	16,911	16,661

Source: Derived from Table 5

Table 7: Estimated population (000S) by age-sex groups for 12 regions of rural Ethiopia, January 1, 1981

Females

	Arssi	Bale	Gondar	Gemu Gofa	Gojam	Hararge	Illubabor	Keffa	Shoa	Sidamo	Wollega	Wollo	Rural Eth.
0-4	143	71	178	92	223	326	62	192	561	271	181	262	2562
5-9	137	73	201	85	208	304	55	174	535	353	179	252	2556
10-14	100	52	149	59	146	190	38	114	425	226	129	180	1808
15-19	60	31	117	42	109	149	28	76	305	149	86	151	1303
20-24	44	19	65	32	74	98	23	55	206	91	53	98	858
25-29	32	19	69	32	72	102	22	66	179	90	49	85	817
30-34	33	13	49	24	64	102	18	58	166	73	48	70	718
35-39	32	19	51	23	59	85	19	68	169	66	50	79	720
40-44	27	13	42	21	51	86	19	57	155	65	39	77	652
45-49	22	13	34	15	43	50	14	44	117	52	30	71	505
50-54	17	8	40	15	39	53	12	30	112	44	30	69	469
55-59	16	8	34	9	26	31	9	23	79	29	18	59	341
60-64	16	11	25	10	22	47	12	33	86	41	25	52	380
65-69	13	6	19	6	17	13	8	13	54	19	16	36	220
70-74	9	4	11	5	14	15	8	13	52	19	15	39	204
75-79	3	2	6	2	5	9	4	5	26	14	9	14	99
80+	7	6	6	5	8	13	12	18	40	17	20	31	183
Regional Total	711	368	1096	477	1180	1673	363	1039	3267	1619	977	1625	14395

Males

0-4	140	71	172	89	221	321	61	197	556	264	174	245	2511
5-9	132	67	178	85	212	285	56	169	554	307	171	246	2462
10-14	87	33	111	49	133	164	32	82	352	188	122	161	1514
15-19	47	23	82	37	94	130	20	58	243	119	73	112	1038
20-24	40	21	71	37	85	123	28	72	203	99	63	82	924
25-29	48	23	71	37	85	142	28	81	219	120	69	93	1016
30-34	43	21	58	31	70	108	27	82	217	85	62	113	917
35-34	38	17	45	26	55	73	22	81	178	80	50	94	759
40-44	26	13	44	20	49	72	19	59	170	68	41	110	691
45-49	20	11	33	13	34	28	13	39	106	48	32	64	441
50-54	21	13	31	13	29	50	15	34	121	35	28	77	467
55-59	14	6	20	10	17	18	8	15	52	17	15	36	228
60-64	17	10	18	7	19	32	15	25	83	24	27	58	335

Table 7 continued

Females

	Arssi	Bale	Condar	Gemu Gofa	Gojam	Hararge	Illubabor	Keffa	Shoa	Sidamo	Wollega	Wollo	Rural Ethiopia
65-69	8	4	8	4	7	7	4	7	42	10	12	22	135
70-74	8	4	6	3	9	16	9	11	38	12	16	29	161
75-79	3	2	2	1	3	1	3	3	14	2	5	8	47
80+	8	4	4	3	6	9	12	11	27	10	27	23	144
Regional Total	700	343	954	465	1128	1579	372	1026	3175	1488	987	1573	13790

Source. The age-sex distribtuion for the regions as at January 1, 1981 derives from Statistical Bulletin No. 46, op.cit, pp. 1-2.

Table 8: Projected population (CCCS) by age and sex for 12 regions of rural Ethiopia, January 1, 1985: first iteration

Males

Age group	Arssi	Dale	Gondar	Gemu Gofa	Gojam	Hararge	Illubabor	Kefa	Shoa	Sidamo	Wollega	Wollo	Rural Ethiop First iterat.	Rural Ethiop 1985 Proj
0-4	171	80	208	110	262	380	70	220	665	320	208	306	3009	3171
5-9	164	82	254	102	245	354	62	208	634	416	206	294	3002	2432
10-14	120	59	174	71	172	221	43	136	504	266	148	210	2124	2043
15-19	72	35	136	50	128	174	32	93	362	176	99	176	1533	1753
20-24	53	21	76	38	87	114	26	66	244	107	61	114	1008	1487
25-29	38	21	80	38	85	119	25	79	212	106	56	99	960	1251
30-34	39	15	57	29	75	119	20	69	197	86	55	92	844	1050
35-39	38	21	59	28	69	99	22	81	200	78	57	92	846	877
40-44	32	15	49	25	60	100	22	68	184	77	45	90	766	726
45-49	32	15	40	18	51	58	16	53	139	61	34	83	599	592
50-54	20	9	47	18	46	62	14	36	133	52	34	81	551	475
55-59	19	9	40	11	31	36	10	27	94	34	21	69	400	371
60-64	19	12	29	12	26	55	14	39	102	48	29	61	446	278
65-69	16	7	22	7	20	15	9	16	64	22	18	42	258	194
70-74	11	5	13	6	16	17	9	16	62	22	17	46	239	121
75-79	4	2	7	2	6	10	5	6	31	17	10	16	116	63
80+	8	7	7	6	9	15	14	21	47	20	23	36	214	27
1985 Region. Projec.	851	415	1278	574	1389	1950	411	1240	3874	1009	1122	1698	-	16911

Females

0-4	172	80	202	100	266	383	81	242	617	315	195	297	2959	3094
5-9	162	85	209	95	255	340	74	207	615	367	191	298	2899	2345
10-14	107	42	130	55	160	196	42	101	391	225	137	195	1780	1971
15-19	58	29	96	41	113	155	26	71	270	142	82	136	1220	1692
20-24	49	27	83	41	102	147	37	88	225	118	71	99	1089	1444
25-29	59	29	83	41	102	170	37	99	243	143	77	113	1198	1226
30-34	53	27	68	35	84	129	36	101	241	102	69	137	1080	1034
35-39	47	22	53	29	66	87	29	99	193	96	56	114	895	867
40-44	31	16	52	22	59	86	25	72	180	81	46	133	813	722
45-49	25	14	39	15	41	33	17	48	118	57	36	78	520	600
50-54	26	16	36	15	35	60	20	42	134	42	31	93	550	490
55-59	17	8	24	11	20	21	11	18	58	20	17	44	269	393
60-64	21	13	21	8	23	38	20	31	92	29	30	70	395	304
65-69	10	5	9	4	8	8	5	9	47	12	13	27	158	219
70-74	10	5	7	3	11	19	12	13	42	14	18	35	190	147
75-79	4	3	2	1	4	1	4	4	16	2	6	10	55	78
80+	10	5	5	3	7	11	16	13	30	12	30	28	170	40
1985 Regs. Proj.	860	435	1121	521	1358	1886	492	1258	3523	1777	1105	1905	-	16661

Table 9: Projected population (000s) by age and sex for 12 regions of rural 1985: Second iteration

Males

	Arssi	Bale	Gondar	Gemu Gofa	Gojam	Hararge	Illubabor	Kefa	Shoa	Sidamo	Wollega	Wollo
0-4	180	84	219	116	277	400	74	241	701	337	219	322
5-9	133	67	190	83	198	287	50	168	514	337	167	238
10-14	115	56	167	68	165	213	41	131	485	256	142	202
15-19	82	40	156	58	147	199	36	106	414	201	113	202
20-24	78	32	112	57	128	168	38	97	360	158	90	169
25-29	50	28	105	50	110	155	32	103	277	138	73	129
30-34	49	18	71	36	94	148	25	86	245	107	69	102
35-39	40	22	62	29	72	103	22	84	208	81	60	96
40-44	31	14	46	24	57	95	20	64	174	73	42	85
45-49	32	14	39	18	50	58	16	52	137	61	34	82
50-54	18	8	40	16	40	53	12	31	115	45	30	70
55-59	18	8	37	10	28	33	9	25	87	32	19	64
60-64	12	8	18	7	16	34	8	25	64	30	18	38
65-69	12	5	17	5	15	11	7	12	48	17	14	32
70-74	5	2	6	3	8	9	5	8	31	11	9	23
75-79	2	1	4	1	3	6	2	3	17	9	6	9
80+	1	1	1	1	1	2	2	3	6	3	3	5
Derived reg. total	857	409	1290	580	1410	1974	402	1239	3881	1895	1106	1867

Females

0-4	180	94	211	104	278	401	84	253	645	330	204	310
5-9	131	69	169	77	206	275	60	168	497	297	155	241
10-14	118	46	144	61	177	217	47	111	433	249	151	216
15-19	80	40	134	58	157	215	37	99	374	197	113	188
20-24	65	35	111	55	136	195	49	117	299	157	94	132
25-29	60	30	85	42	105	174	38	102	249	147	79	115
30-34	51	25	65	33	81	123	34	96	230	97	66	131
35-39	45	21	57	28	64	84	28	96	191	93	54	110
40-44	27	15	46	20	52	76	22	64	168	72	41	118
45-49	28	16	45	17	47	39	20	55	136	66	41	90
50-54	23	15	32	13	31	53	18	37	120	37	28	83
55-59	25	11	34	16	30	31	15	27	84	30	25	64
60-64	23	10	16	6	18	29	15	24	71	22	23	54
65-69	19	7	13	6	12	12	7	12	65	17	19	37
70-74	13	4	5	3	8	14	9	10	31	11	13	26
75-79	5	4	3	2	5	2	6	5	22	3	8	14
80+	2	1	1	1	2	3	4	3	7	3	7	7
Derived Regional total	879	443	1168	542	1409	1944	493	1279	3621	1826	1121	1936

Table 10: Projected population (000S) by age and sex for 12 regions of rural Ethiopia January 1, 1965: final iteration

Males

	Arssi	Bale	Gondar	Gemu Gofa	Gojam	Hararge	Illubabor	Kefa	Shoa	Sidamo	Wollega	Wollo
0-4	179	86	217	115	272	395	76	242	700	339	222	328
5-9	132	60	188	82	195	283	52	168	513	340	169	242
10-14	114	57	166	67	163	210	42	131	484	258	144	206
15-19	82	41	155	57	145	196	37	107	413	202	115	205
20-24	77	32	111	56	127	166	39	97	360	159	91	173
25-29	50	28	104	49	109	153	33	103	276	139	74	132
30-34	49	19	70	35	92	146	26	86	245	108	70	103
35-39	39	23	61	28	71	101	23	84	207	81	60	97
40-44	30	14	46	24	56	94	21	64	174	73	43	87
45-49	32	15	39	18	49	57	16	52	137	61	35	83
50-54	17	8	40	15	39	53	12	31	114	45	30	71
55-59	18	8	36	10	28	33	10	25	87	32	19	65
60-64	12	8	18	7	16	34	9	25	63	30	18	36
65-69	12	5	16	5	19	11	7	12	48	17	14	32
70-74	5	2	6	3	8	9	5	8	31	11	9	23
75-79	2	1	4	1	3	6	3	3	17	9	6	9
80+	1	1	1	1	1	2	2	3	6	3	3	5

Females

0-4	181	95	208	103	275	399	66	255	644	329	206	313
5-9	132	69	167	76	204	274	61	169	496	296	157	243
10-14	110	47	142	60	175	216	48	112	432	248	153	218
15-19	80	41	132	57	155	214	30	100	374	197	115	190
20-24	65	36	109	54	134	194	50	110	295	157	95	133
25-29	61	30	84	42	104	173	39	103	248	147	80	116
30-34	51	26	64	33	80	123	35	97	230	97	67	132
35-39	45	21	50	28	63	84	29	97	191	92	55	111
40-44	27	15	45	20	52	76	23	65	167	72	41	119
45-49	28	16	44	17	47	38	20	56	135	66	42	90
50-54	23	15	32	13	31	53	18	37	119	37	28	84
55-59	25	11	34	16	30	31	16	27	84	30	25	64
60-64	16	10	16	6	17	29	16	24	71	22	23	54
65-69	14	7	13	6	12	12	7	12	64	16	19	37
70-74	7	4	5	2	8	14	9	10	31	11	13	26
75-79	5	4	3	2	5	2	6	5	22	3	8	14
80+	2	1	1	1	2	3	4	3	7	3	7	7

REFERENCES

Adepoju, A. et al — Internal Migration in Nigeria (University of Ife: Ile-Ife, 1976)

Baum, S., — Some aspects of population projections in developed market economies", in Population projections: problems and solutions (United Nations: New York, 1981).

Inoue, S., — 'Evaluation of population projections for developing countries', in United Nations (1981), op. cit

Isupov, A.A., — "Population projections in the USSR and other European Socialist countries," in United Nations (1981), op.cit.

UNECA — Report of the regional training workshop on demographic estimates and projections in Africa, Accra (Ghana), July 15-29, 1985 Vol. 2, pp. 156

Shryock, H. and Siegel, J., — The methods and materials of Demography (Washington D.C., 1971)

Zachariah, K.C., — 'Internal migration and subnational population projections in United Nations (1981), op. cit.

United Nations — Methods of measuring internal migration Manual VI (United Nations: New York, 1970)